Type 1 and Type 0 Resetting

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and leg. Although commonly used in the clinic, this is a relatively crude and unreliable measure that does not reflect the true spatial resolution of the system.

►Haptics
►Processing of Tactile Stimuli

Two-Process Model of Sleep Regulation

Definition

The two processes of Alexander Borbély's two process model of sleep regulation (Hum Neurobiol 1:195–204, 1982). A propensity for sleep increases during wakefulness and dissipates during sleep. In the model this homeostatic sleep process was referred to as Process S, and its dynamics are derived from the sleep-wake dependent changes in electromyographic (EEG) slow-wave activity. Process S interacts with a circadian process, Process C. Process C defines an upper and a lower threshold between which Process S oscillates. Sleep onset is triggered when Process S reaches the upper threshold and sleep continues until Process S reaches the lower threshold. The thresholds were estimated on the relationship between sleep duration and circadian time at which sleep is initiated and on the dynamics of EEG slow wave activity (see Process S).

►Electromyography

Two-Third Power Law

Definition

The two-third power law prescribes that the angular velocity ω and curvature k of curved movements are related by the power law $\omega = Ck^{2/3}$ with C a constant. Using tangential velocity v, this relation can be rewritten as $v = Ck^{-1/3}$. This relation has a phenomenological basis but can be derived under the assumption that curved movements are produced by sine and cosine modulated orthogonal components. It can also be derived with the assumption that movements minimize jerk (optimize smoothness).

►Motor Control Models

Tylotrich Hairs

Definition

Hairs are classified in terms of stiffness; down hair, guard hair, a Tylotrich hair. Tylotrich hairs are most biggest and strong hairs except vibrissae, and often associated with touch dome. But they are lacking in primates.

►Cutaneous Mechanoreceptors, Anatomical Characteristics

Tympanal Organ

Definition

A type of mechanoreceptor used to detect acoustic signals that is normally associated with a thinned region of cuticle – the tympanic membrane – whose motion directly corresponds to the pressure changes of an acoustic stimulus in the surrounding medium.

►Invertebrate Ears and Hearing

Type 1 and Type 0 Resetting

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Synonyms

Weak and strong resetting

Definition

Type 1 and Type 0 resetting describe two qualitatively different response-types of a ►circadian rhythm to a ►zeitgeber stimulus. Circadian rhythms are circa 24-h oscillations in, e.g., sleep-wake behavior, secretion of certain hormones, gene expression and a multitude of other processes; zeitgebers are those signals from the environment which organisms can use to synchronize (entrain) their biological clock to the 24-h day. When circadian rhythms "run free" in constant conditions, their period often deviates from 24 h. Stable ►entrainment is achieved when a zeitgeber stimulus can shift the phase of the circadian rhythms each day by the exact amount that compensates the difference between the ►free-running period and that of the zeitgeber (normally 24 h).

Characteristics

When a free-running period is shorter than 24 h (e.g., 22 h), the circadian rhythm has to be delayed (in this case by 2 h, every day); if it is longer, it has to be advanced. This type of entrainment is called type 1. To achieve a type 1 entrainment, the rhythm has to respond differently to a zeitgeber stimulus (with a given duration and a given strength) depending on its internal phase. In general, circadian clocks are advanced when they receive a light pulse during the second half of their internal night, are relatively unresponsive during their internal day, and respond with a delay in the first half of their internal night. The characteristic which represents this phase-dependent response is called ►phase response curve (►PRC). In type 1 ►resetting, the resulting phase (i.e., where it ends up after having been shifted) depends on when during its cycle it received the light pulse.

Another possibility to synchronise circadian rhythms with their cyclic environment is if every zeitgeber stimulus – no matter when it is received – resets the rhythm to the same internal phase (e.g., to the beginning of the internal day). This type of resetting is called type 0. In type 0 resetting, the resulting phase is independent of the timing of the zeitgeber stimulus. In analogy to a board game, type-1 resetting is like drawing cards that tell you to move x spaces forward or backward, while type 0 refers to the cards that always send you back to "Go." Type 1 resetting refers to weak responses where even the maximal advance or delay is less than half a cycle while in type 0 resetting the maximal phase shift is always as long as the entire cycle. Since the response to a zeitgeber stimulus depends on its strength (both intensity and duration), a type 1 resetting characteristic can be transformed into a type 0 by increasing the zeitgeber strength.

Circadian Clocks are Built for Entrainment

►Circadian rhythms are biological oscillations that occur with a frequency of approximately once per 24 hours when an organism is held in constant conditions (hence, circadian from *circa dies, Latin,* or about a day). These self-sustained rhythms occur in organisms from all phyla, regulating biology from the level of gene expression to behavior (see also ►chronobiology).

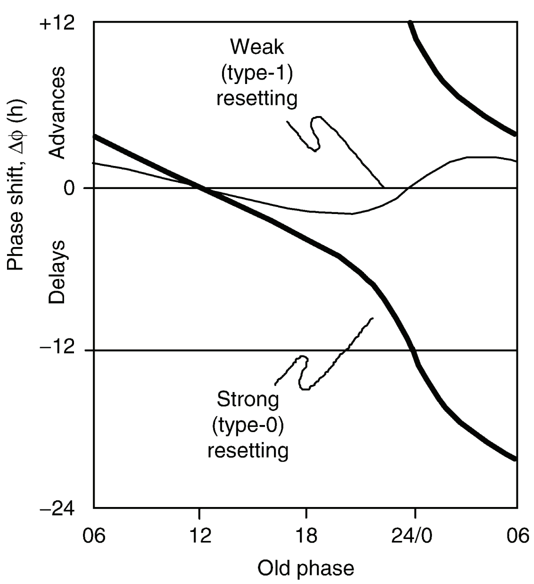
Considering that virtually all living things have evolved in a cycling environment, the "constant conditions" often used to investigate circadian clocks are rather artificial. In nature, circadian clocks are virtually always entrained to their cyclic environment [1,2]. In nature ALL zeitgebers are caused directly or indirectly by the rotation of the Earth around its axis thereby regularly exposing different parts of the globe to sunlight. Thus, all non-photic cyclic parameters, from temperature to the availability of food or the threat of predators, ultimately depend on light. It is, therefore, not surprising that light is the most prominent zeitgeber for circadian clocks although, theoretically all other, light-dependent parameters could also be used as (non-photic) zeitgebers [3]. In addition to the richness of the temporal physical environment, the daily alternations of light and darkness alone have complex characteristics. They can change in amplitude (for example, for organisms that are either exposed to direct sunlight or those living in shaded niches); their duration (►photoperiod) can change over the course of the year, or the duration of dawn and dusk periods can be different at higher latitudes compared to the equator. Even their spectral characteristics can be different (for example, for organisms living in the ocean compared to those living on a glacier).

The question of how exactly the alternating exposure to light and darkness entrains circadian clocks remains a topic of debate. Are only the changes (transitions) from light to dark and vice versa important cues for entrainment, or does the cyclic light environment entrain the clock by continuously influencing its progression? The former is called non-parametric entrainment, the latter parametric. These two hypotheses for explaining entrainment had prominent representatives among the pioneers of our field. While Pittendrigh favored the non-parametric hypothesis, Aschoff favored the parametric view [4,5]. While the former heavily relies on the phase response curve, the latter believes that entrainment is achieved by a continuous influence of the changing light levels on the rhythm's period, thus using a ►velocity or *tau* ►response curve. As always, the truth probably lies in between the two hypotheses. Depending on the niche of an organism or depending on the time of year, a combination of parametric and non-parametric will eventually explain how circadian clocks are entrained. The fact that both parametric and non-parametric entrainment occur in nature is demonstrated by the finding that some organisms entrain perfectly without ever experiencing dawn or dusk [6].

Phase Response Curves Come in Different Shapes

The non-parametric hypothesis favors the lights-on and -off signals as the key to entrainment. Although natural photoperiods consist of extended blocks of light and darkness, single steps (from light to darkness or from darkness to light) or even light pulses as short as a flash can predictably shift (reset) the phase of a circadian rhythm, and if they occur in regular intervals, they can entrain the clock. A prerequisite for such an entrainment mechanism is that the clock responds differently to the same stimulus (e.g., pulse of light) depending on when it receives the stimulus during its cycle resulting in a phase response curve (PRC). While entrainment protocols involve a regular repetition of a zeitgeber, PRCs are constructed by measuring the direction and magnitude of phase shift to a single stimulus given at different internal phase in otherwise constant conditions.

Internal phase refers to a time within the ►circadian cycle that corresponds to an arbitrarily designated but, nevertheless, identifiable "event" of the rhythm that is being measured. Such an "event" could be, for example, the trough of a circadian temperature rhythm or the onset of activity following the main sleeping bout. For the construction of a PRC, the zeitgeber (e.g., a light pulse) is applied – in separate experiments – at different phases of the cycle (2h, 4h, 6h, etc. after, e.g., the activity onset) and the resulting phase of the rhythm (e.g., of the activity onset) is compared to that of a control experiment where the rhythm ran free without a perturbation. This comparison yields the phase shift which is elicited by a light pulse given at a specific internal time which can be either delayed, advanced or not shifted at all. The resulting phase shifts induced over an entire circadian cycle are then plotted as a phase response curve (PRC, see Fig. 1). A typical type-1 PRC shows phase advances (in the second half of the internal night), phase delays (in the first half of the internal night) and a non-responsive "►dead zone" (in the middle of the internal day) [7]. For a collection of most known PRC's, see www.cas.vanderbilt.edu/johnsonlab/prcatlas/index.html).



Type 1 and Type 0 Resetting. Figure 1 Phase response curves can show strong or weak resetting in response to a zeitgeber. The stimulus is delivered at a given circadian time (old phase) and, some days later, the new phase is determined. This phase shift is plotted either as an advance, a delay or no change. Reprinted from [2].

PRCs can be plotted in two different ways. In most cases, the amount of phase shift elicited (y-axis) is plotted against the internal phase at which the pulse was given (x-axis). By convention, internal phase is either expressed as Circadian Time [8] (CT; anchored at the time at which lights would have been turned on, defined as CT0) or Internal Time [9] (IT, anchored at mid-night, i.e., at the mid-point between the times at which lights would have been turned off and on, defined as IT0). An alternative graphing method, called a Phase Transition Curve (PTC), plots the (new) phase which results from the perturbation of the zeitgeber stimulus (y-axis) against the internal phase at which the pulse was given (x-axis). The labels "type 1" and "type 0" resetting are derived from the slopes of the PTC. If the stimulus always resets the ►oscillator to a given phase, the slope of the PTC is zero ("go back to start," no matter where you are); if, however, the stimulus shifts the phase by a certain amount, which changes depending on the internal time when it was given, the slope will be close to one. The stronger the zeitgeber stimulus, the more it will shift the phase, the more the individual phase shifts within a PRC, the more the PTC will deviate from a slope of 1 With strong resetting, the slope approaches 0 (almost complete resetting).

PRC's and Circadian Entrainment

Experiments probing how a given zeitgeber affects the phase of a free running circadian rhythm have been remarkably successful in providing a theoretical basis for entrainment. To do this, one puts the zeitgeber period (T), the free-running period (τ), and the PRC into a systematic relationship. The daily phase shifts (ΔØ) necessary to ensure stable entrainment must (exactly) compensate for the difference between T and τ: $\Delta Ø = \tau - T$. Thus, by definition, delays are negative and advances positive. Stable entrainment can only be achieved if one point on the PRC represents the necessary ΔØ, and this is exactly the phase at which the zeitgeber pulse must be given to the oscillator every day. If entrainment was achieved predominantly non-parametrically, e.g., if it was the signal of dawn which ensures entrainment, then the phase of entrainment (chronotype) is determined by the period of the zeitgeber cycle (in nature 24 h), the shape of the PRC and the free-running rhythm.

Significance of Type 1 and Type 0 Resetting in the Natural Environment

Entrainment is the basis for the variety in temporal aspects of human behavior (as well as that of most organisms on earth), exemplified by the well known "early" or "late" type individuals (chronotypes), those who either retire and rise early or late within the day. Both the free-running rhythm and the shape and amplitude of a PRC can vary between species but it can also vary between individuals within a species. It can even change over the lifetime of an individual. Each species and each individual within a species and even an individual at different ages can, therefore, show a different phase of entrainment (be a different chronotype). In real life, the strength of the stimulus (or the sensitivity to the stimulus) will have an impact on the free running period and the PRC, and will thus also contribute to chronotype. For humans, this would relate to people living and working predominantly indoors compared to those working outdoors.

The shape of the PRC which has evolved for a given species generally reflects the relationship between T and τ. If for example, the $\tau < T$, the PRC should have a substantial delay portion; if $\tau < T$, the PRC will have to show a substantial advance portion. There is yet another parameter that influences the relationship between T, τ and the PRC – the more robust a rhythm, the larger its amplitude, the less it will be perturbed by a given zeitgeber stimulus. Robust (high amplitude) circadian clocks would, therefore, predictably show rather a type 1 than a type 0 resetting characteristic. Although this can be explained by simple mechanical oscillator theory, it may also make sense in biology, as can be shown by the example of aging. Young animals (including humans) generally have a more robust circadian oscillator, expose themselves to stronger zeitgeber stimuli and their input pathways are more sensitive compared to older animals, yet clocks of all ages need be entrainable. In this case, the decreased exposure to strong zeitgeber stimuli in the elderly would be compensated for by a decreased robustness (amplitude) of their circadian system.

References

1. Johnson CH, Elliott JA, Foster R (2003) Entrainment of circadian programs. Chronobiol Int 20(5):741–774
2. Roenneberg T, Daan S, Merrow M (2003) The art of entrainment. J Biol Rhythms 18(3):183–194
3. Roenneberg T, Foster RG (1997) Twilight times - ight and the circadian system. Photochem Photobiol 66:549–561
4. Pittendrigh CS (ed) (1981) Circadian systems: entrainment. In: AschoffJ (ed) Biological rhythms, vol. 4. Plenum Publishers, New York, pp 95–124
5. Pittendrigh CS, Daan S (1976) A functional analysis of circadian pacemakers in nocturnal rodents. IV. Entrainment: pacemaker as clock. J Comp Physiol A 106:291–331
6. Hut RA, Van Oort BE, Daan S (1999) Natural entrainment without dawn and dusk: the case of the European ground squirrel (Spermophilus citellus). J Biol Rhythms 14(4):290–299
7. Pittendrigh CS, Minis DH (1964) The entrainment of circadian oscillators by light and their role as photoperiodic clocks. Am Nat 158:261–294
8. Pittendrigh CS, Minis DH (1964) The entrainment of circadian oscillations by light and their role as photoperiod clocks. Am Nat 98:261–294
9. Daan S, Merrow M, Roenneberg T (2002) External time - internal time. J Biol Rhythms 17(2):107–109

L-type Ca^{2+} Channel

Definition

The L-type calcium channel is the dihydropyridinesensitive Cav1.2 calcium channel, that is essential for smooth muscle contraction and the target for the calcium channel blocker/calcium antagonists.

►Calcium Channels – an Overview

Type I Position-Vestibular-Pause (PVP) Neuron

Definition

Neurons in the vestibular nuclei, which constitute most of the intermediate leg of the direct vestibulo-ocular reflex (VOR) pathway.

►Position-Vestibular-Pause Neurons
►Vestibular Nuclei
►Vestibulo-Ocular Reflexes

Type I Secondary Vestibular Neurons

Definition

Vestibular nucleus neurons that receive a primary afferent input from the ipsilateral horizontal semicircular canal. They show type I response to head rotation in